AN ENGINEERING DESIGN OF THE CONSOLIDATED FIRE STATION WRIGHT-PATTERSON AFB, OHIO

GROUP DESIGN PROJECT

GCE/MC/76S-2 1976 Graduate Class

Civil Engineering/Facilities

EXECUTIVE SUMMARY

GCE/MC/76S-2

AN ENGINEERING DESIGN
OF THE CONSOLIDATED FIRE STATION
WRIGHT-PATTERSON AFB, OHIO
(Volume I - Executive Summary)

GROUP DESIGN PROJECT

Presented to the Faculty of the School of Engineering

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Requirements for the Degree of

Master of Science

by

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PREFACE

This design study was undertaken by members of the 1976 class in Civil Engineering/Facilities in partial fulfillment of the requirements for a Master of Science Degree. The class members are officers from the U. S. Army Corps of Engineers and the U. S. Air Force Civil Engineering and Services Branch. The purpose of the Facility Systems Integration Study is to apply an integrated engineering approach to a facility design project that would be of benefit to the Air Force.

This report consists fo two volumes: Volume I is the executive summary, and Volume II is the main text and appendices of the design study.

Grateful appreciation is expressed to many who were instrumental in the successful completion of this design. In particular, we thank our sponsor, Col. Robb, Base Civil Engineer at Wright-Patterson AFB, and his staff who provided outstanding support for this project. We would also like to acknowledge our faculty advisors at the Air Force Institute of Technology for their patience, guidance and technical advice.

The Authors

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ABSTRACT

An engineering design study was conducted on a proposed consolidated fire station for Wright-Patterson Air Force Base. The goal of the study was to design a specific facility after examining alternate methods of construction and different building materials. Six functional floor plans were considered in the design. The floor plan selected was analyzed using six different structural schemes. A single story design with a drive through capability was selected using a combined steel frame with load-bearing and non load-bearing concrete masonry walls. A variable volume air conditioning system was selected for installation in the station on the basis of economy. A perimeter circulating hot water heating system was designed. Hot water will be generated for the heating system by a heat exchanger using steam from a base central heating plant. Solar energy was considered as an energy source but was found to be uneconomical. A complete electrical design was accomplished using 208/120 volt power supplied through a 150 KVA transformer. An emergency electrical system was incorporated into the electrical design which will use a 30 KW Diesel generator with an automatic start and load transfer capability. The design provides for a fire detection system and an intercom system within the station. Total cost of the facility was estimated to be $555,200 or $34.43 per square foot of floor area. This figure compares closely to the estimate contained in Mean's Building Construction Cost Data 1975 of $34.20 per square foot for a fire station.

I. Introduction

One of the critical services on an Air Force Base is fire protection. Currently the physical facilities on Wright-Patterson AFB are outdated, physically separated, and marginally adequate. None of the current facilities were designed to support a fire and rescue mission. The fire and crash rescue equipment is stored at three different locations in areas A and C of the base; the main fire station, the flight line station, and a hangar.

A new facility, designed as a fire station, has been programmed for Wright-Patterson AFB to consolidate the fire protection functions of areas A and C under one roof. The new facility will reduce operational costs and manpower requirements, and will improve the operational efficiency of the fire department.

The objective of this study was to prepare a design for a fire station to be constructed at Wright-Patterson Air Force Base. In this design an attempt has been made to determine the best functional efficiency at the least life-cycle structural cost. This station will house and provide routine maintenance facilities for 14 vehicles, ranging in size from small pick-up trucks to large crash and structural fire trucks. The design provides for offices, training rooms, sleeping quarters, dining facilities, and recreational facilities for approximately 20 men per shift.

The design includes a functional layout for the station; the design of the structural components; the design of the mechanical systems for heating, ventilating, and air conditioning; and the design of the electrical distribution system, including an emergency power system.

The design study includes sketches of the floor plan, typical wall sections, and a layout of the mechanical and electrical systems. Adequate capacity has been provided in the electrical system for typical communication systems. Two types of fire alarm systems were considered; a system similar to the one currently in use on the base, and a teletype terminal connected to an Energy Monitoring Control System. Provisions for connection of either type of alarm system are provided. The design also includes specifications of the types of materials and equipment to be used in construction based upon functional requirements and least cost as determined by economy of operation and life cycle costing.

Comments concerning deficiencies in present fire stations and recommended changes in future fire station designs were solicited from both civilian and military personnel. An analysis of these comments formed the basis for the proposed functional layout of the structure. The mechanical and electrical systems were designed within the limitations imposed by the layout of the basic structure.

The results of this design are presented in Volume I by engineering discipline, beginning with the civil and followed by the electrical and mechanical designs. The detailed discussions of assumptions made and alternatives investigated are contained in Volume II.

II. Civil Engineering

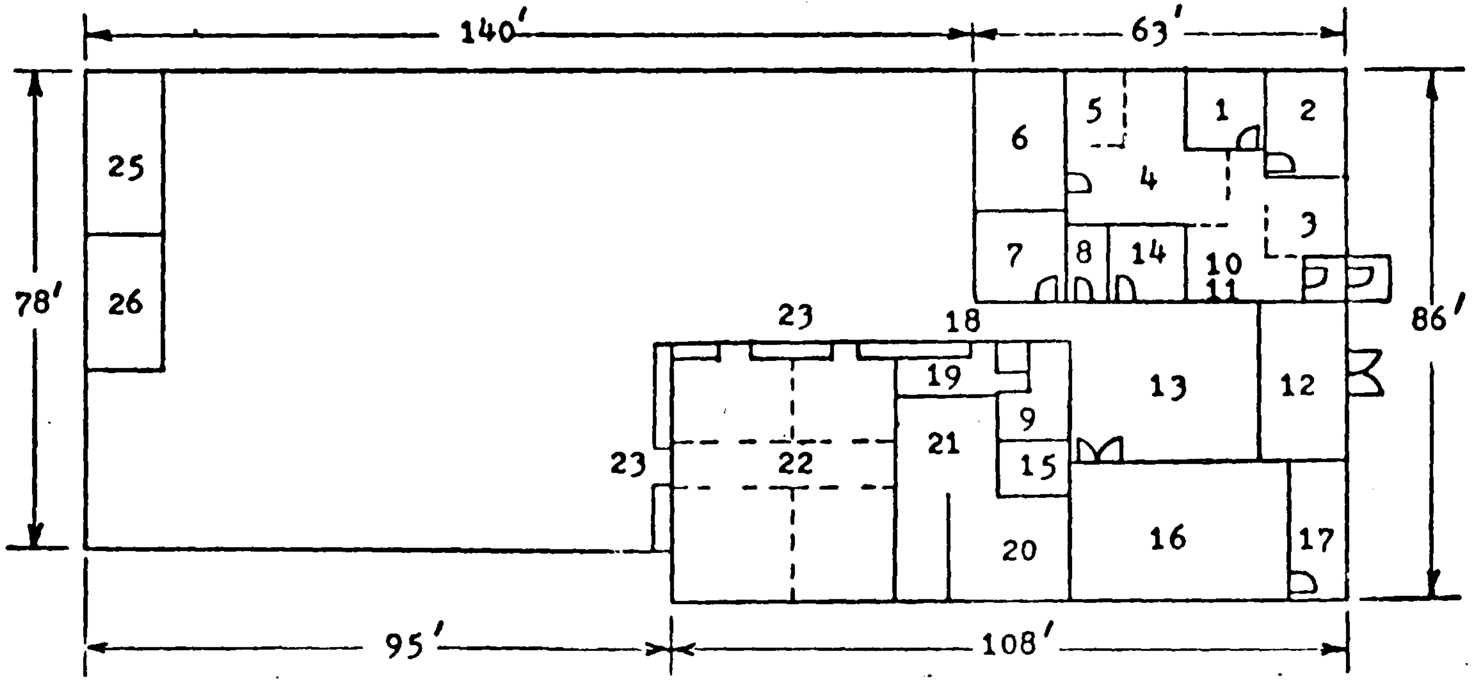
Functional Layout

Six functional layouts were analyzed based upon criteria established early in the design. The most important criterion was rapid access to the firefighting equipment from any location in the building. Secondly, a drive through capability for the large vehicles was considered a necessary design feature. The third most important criterion was that the consolidated fire station be designed to best satisfy the differing needs of all the occupants; the firefighters work a 24 hour shift while the administrative personnel work a normal eight hour day. This dictated a separation within the facility for better operational and administrative efficiency. Based on these major criteria plus other factors covered in Volume II of this report, the functional layout was designed. This floor plan is illustrated in figure 1.

Roof Section

The roof was designed to withstand a uniform load of 55 pounds per square foot (psf). This design load was based on a live load of 30 psf plus a dead load of 25 psf. A built up roof was chosen as the type to be designed.

In order to arrive at the most economical design, a number of alternative materials were analyzed as possible choices for the roof section. Materials considered as possible components in the roof design were light-weight vermiculite concrete, fiberglass, and polystyrene insulation, and a four ply roof covering with a fiberglass cap sheet.



1	Branch Chief	10	Secretary	19	Ladies Latrine
2	Conference Room	11	Closet	20	Mens Latrine
3	Fire Protection Eng	12	Mechanical	21	Locker Room
4	Tech Services Office	13	Lounge/Rec	22	Personnel Qtrs
5	Tech Services Chief	14	Unit Chief	23	Bunker Lockers
6	Tech Services Shop	15	Training officer	24	Apparatus Bay
7	Alarm Room	16	Dining/Classroom	25	Equipment Maint
8	Latrine	17	Food Preparation	26	Supply
9	Assistant Chief	18	Janitor Closet		

Figure 1. Fire Station 1 Floor Plan

Structural Scheme

Six structural designs were considered for the chosen functional layout. Features of the various designs considered included reinforced concrete framing; steel framing using wide flange beams, girders, and columns; load-bearing concrete masonry unit (CMU) walls; concrete filled tubular columns, and longspan steel joists. The structural scheme selected is a combination steel frame with non load-bearing CMU shear walls in the apparatus bays, and load-bearing CMU shear walls in the administrative area. Concrete filled tubular columns were used in the steel framed portion of the structure and longspan steel joists were used throughout. The cost of all six designs considered were within a three precent range of each other. The selected design permitted the maximum flexibility while exhibiting sound structural integrity.

Wall Design

Wall composition and design, both for the interior and exterior locations, were determined to be a function of the structural, acoustical, and the thermal requirements of the building. Because the proposed building site is located in the Wright-Patterson AFB Compatible Use District (CUD) 7, approximately on the Noise Exposure Forecast (NEF) 43 contour, sound control considerations in the form of a Noise Level Reduction (NLR) of 30 db in the apparatus bays and administrative areas and a NLR of 35 db in the crew quarters were incorporated into the design. Seismic considerations were incorporated into the wall design to account for the fact that Wright-Patterson AFB is in seismic zone 2. In addition, the exterior walls were designed to act as shear walls to resist the

wind and earthquake loads. All structural wall sections were designed using CMU construction.

Foundations

The foundation consists of reinforced concrete spread column footings and continuous concrete wall footings. The design of foundations was accomplished without a detailed knowledge of the existing soil conditions.[1] Before actual construction is started, it will be necessary to redesign the foundations based on actual soil boring data.

[1] The site is now covered by an 11 inch thick reinforced concrete hardstand constructed in 1943; no current soil boring data was available.

III. Electrical Engineering

Introduction

The design of the electrical system for the fire station included the lighting system, the electrical distribution network, an emergency power supply, a fire detection system and a station intercom. Short circuit analysis and a coordination study were accomplished to insure adequate protection.

Electrical Loads

Electrical loads were determined from manufacturers' data on equipment selected for use and from the National Electrical Code 1975. The total connected electrical load was 183 KVA. Using an overall demand factor of 0.75, the demand load was determined to be 137 KVA.

Distribution System

The underground base primary distribution system is a 12,000 volt, three wire system. The distribution system employed within the fire station is a radial system with most of the electrical demand being 120 volt, single phase. The transformer selected for use is a pad mounted, three phase, 150 KVA, 12,000 volt, delta-208/120 volt grounded wye. Electrical circuits throughout the station consist of THW copper conductors and EMT conduit. Total estimated cost of the electrical distribution system, excluding emergency power, is $37,096.

Lighting Design

A lighting design was accomplished for all areas within the fire station. Four different lighting systems were compared and the final selection was based on an economic analysis. The final lighting system consists of a combination of high pressure sodium, fluorescent, and incandescent luminaires. Estimated cost of the lighting system is $20,555.

Short Circuit Analysis

Short circuit current on both the primary and secondary side of the transformer was determined to be 10,921 amperes and 6933 amperes, respectively. The maximum contribution to the short circuit current from electrical equipment within the fire station is 370 amperes. Fuses on the primary side of the transformer were selected to provide adequate protection for the transformer. All circuit breakers within the station have 10,000 ampere interrupting capacity and are sized in accordance with the National Electrical Code 1975.

Coordination

A coordination study was performed for the main disconnect/circuit breaker in the station, the fuses on the primary side of the transformer, and the relays protecting the base primary feeder. Protective devices were selected so that the circuit breaker would trip out first, followed by the primary fuses, and then the base relays.

Emergency Power

Emergency power is provided for critical lighting throughout the station, all circuits in the alarm room, and the overhead doors in the apparatus bay. Emergency lighting is a combination of lighting circuits connected to an emergency generator and self-contained battery powered lights. The emergency generator is a Diesel powered 30 KW, MB-18, with automatic start and load transfer capability. Estimated cost of the emergency power and lighting system is $14,611.

Alarm Room

Fire alarms from facilities on base may be received in the alarm room in two ways. The first is by a 250-300 zone alarm panel similar to the one now in use at the present fire station. Cost of a 300 zone panel is about $16,000. The second method for receiving alarms is through connection to an Energy Monitoring Control System. The only equipment required in the alarm room for this system is a teletype receiver. Since it is not known which system will be used in the future, electrical power for both systems is provided.

An intercom system with the master control in the alarm room is provided at an estimated installed cost of $2,923.

Alarm alert bells, controlled by the alarm room operator, are provided both inside and outside the station at an estimated installed cost of $359.

Total estimated cost for the alarm room systems, including a 300 zone alarm panel, is $19,282.

Fire Detection System

The fire detection system consists of two smoke detectors in the sleeping quarters and rate compensation/fixed temperature sensors throughout the remainder of the building. Estimated cost of this system is $2,171.

Total Electrical Costs

Total cost for the electrical systems, excluding general contractor's overhead and profit, is estimated to be $93,715.

IV. Mechanical Engineering

Introduction

The mechanical systems for the fire station are grouped into the following four major categories;

A. Air conditioning system

B. Heating system

C. Ventilation and exhaust systems

D. Plumbing system and kitchen design.

A discussion of the salient features of each of these mechanical systems is contained in the following sections of this report.

With the present interest in alternative energy sources, solar energy was considered as a possible source for heating and cooling applications in the fire station. This energy source proved to be uneconomical and therefore was eliminated from consideration.

Design Criteria and Load Estimating

The design parameters used to calculate the heating and cooling loads were taken from the applicable sections of AFM 88-8, Chapter 6 and AFM 88-15.

A computer program called LOADCALC, which uses the Carrier method of load estimating, was used to assist in the cooling load calculations. The maximum cooling load was estimated to be 120,000 BTUH, and occurs at 1600 hours in July. The maximum heating load was estimated to be 640,000 BTUH.

Air Conditioning System Selection

In order to avoid overcooling some of the rooms in the fire station

while undercooling others, the air conditioning system must be capable of varying its cooling capacity in several different areas of the fire station simultaneously. After considering numerous types of systems which provide this kind of control, an all-air type system was selected.

Two types of all-air systems were compared in detail; a multizone unit system and a variable volume system. In order to estimate initial installation and operating costs, designs for both types of systems were accomplished. The electrical energy consumption of each type system was estimated using the Rational Energy Analysis Procedure developed by the Carrier Corporation. Based on an economic analysis, a variable volume system was chosen for the fire station.

Air Conditioning System Description

The variable volume system consists of a central station air handling apparatus capable of delivering 3540 CFM at 3 inches water gauge static pressure, a ten ton air cooled direct expansion condensing unit, a medium pressure dectwork system, variable volume air distribution terminals, and automatic controls. Figure 2 is a schematic diagram of the variable volume system.

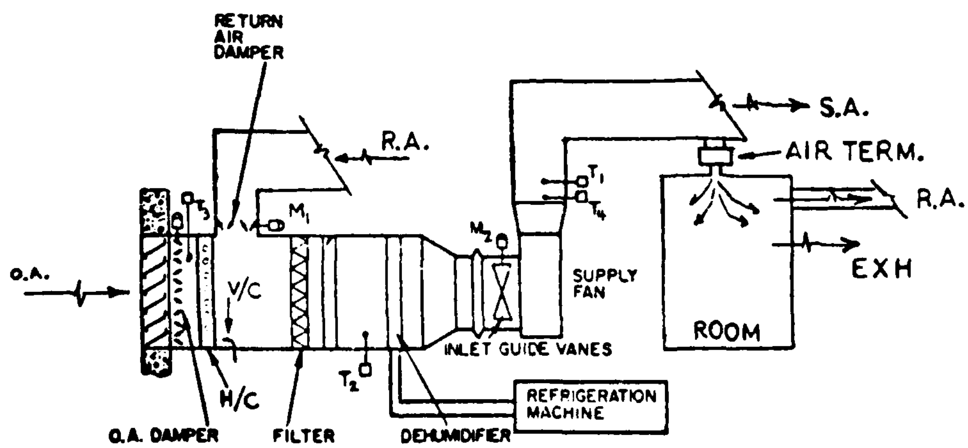


Figure 2. Variable Volume System Schematic Diagram

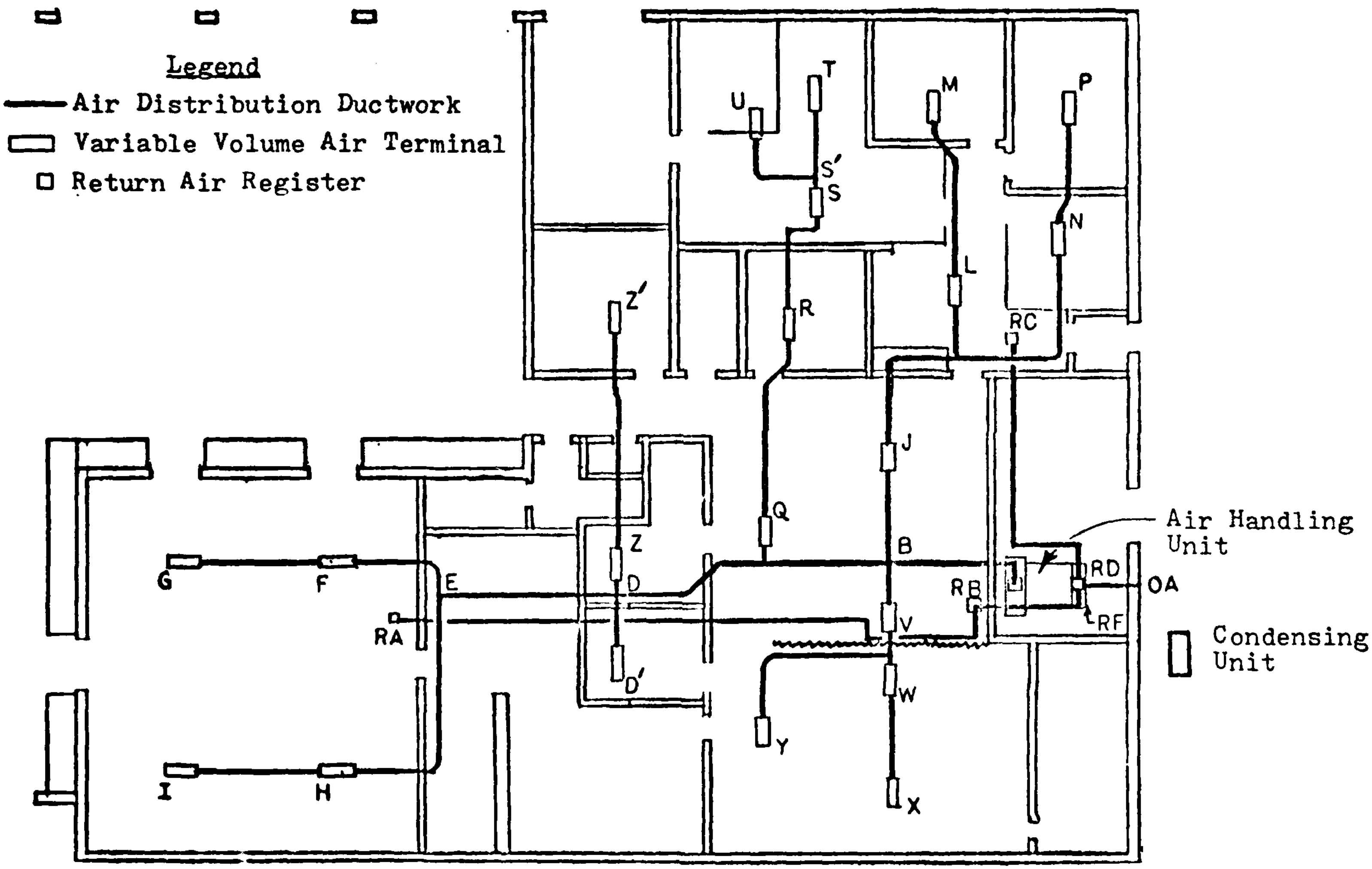


Figure 3. Air Conditioning Plan

Figure 3 is a basic floor plan showing the physical location of the system components. The estimated cost of the air conditioning system is $24,172.

Heating System

The heating system was designed to offset the transmission heat losses thru walls, windows, and the roof, and to offset the heat losses due to infiltration and outside ventilation air.

A reverse return circulating hot water perimeter heating system was chosen to complement the variable volume air conditioning system. The heating devices chosen were of two basic types; finned-tube radiators and unit heaters. The temperature of the circulating hot water is reset according to outside air temperature. Hot water is generated by a heat exchanger utilizing steam from the base central steam system. The system heating capacity is 640,000 BTUH. Figure 4 shows the heating system layout. The installed cost of the heating system is estimated at $14,569.

Air Conditioning and Heating System Control

In the operation of the air conditioning system, the air handler provides a supply of air to each of the variable volume air terminals. The cooling capacity of the air terminals is regulated by self-contained controls to maintain a room temperature of 78°F.

When ambient air temperature is below 60°F, outside air is used for cooling. When the ambient air temperature is above 60°F, cooling is accomplished using the mechanical refrigeration system.

The hot water perimeter heating system is controlled by a separate

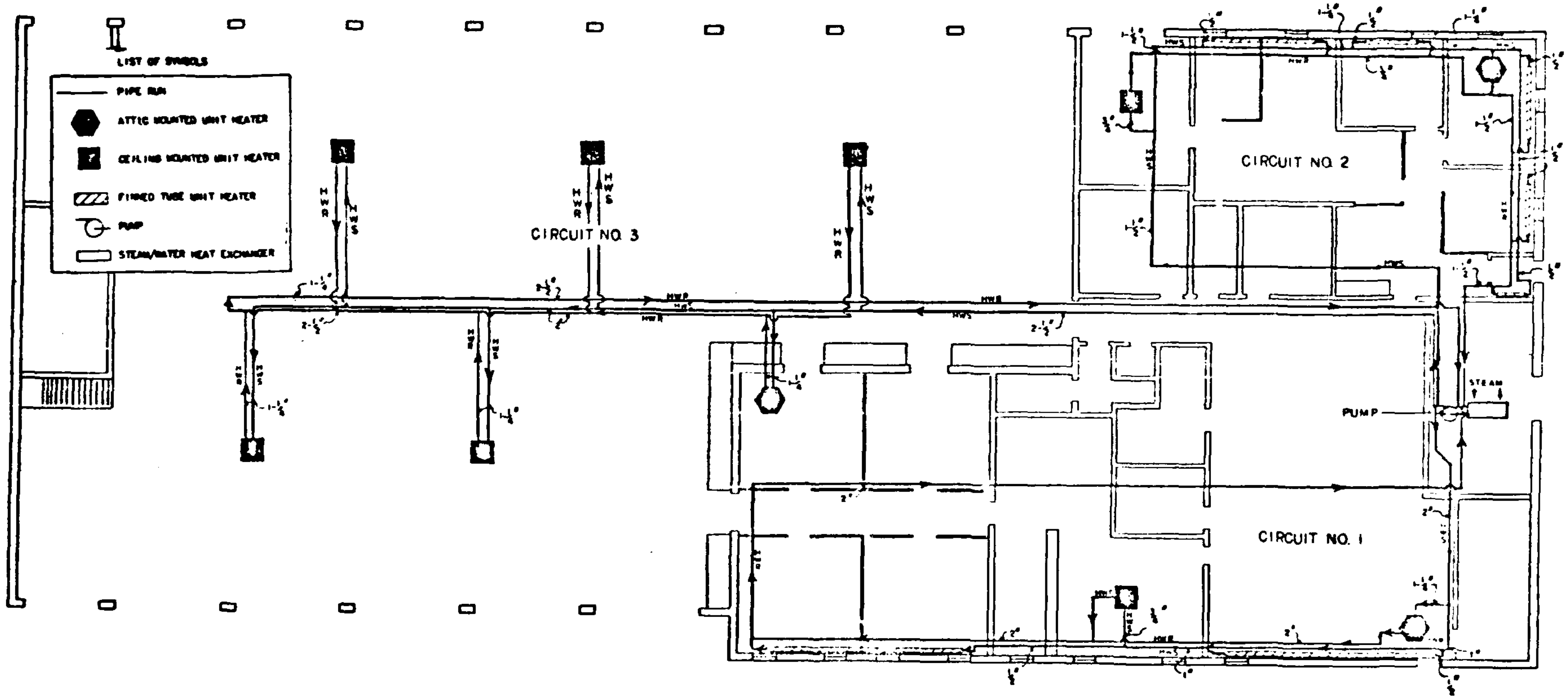


Figure 4. Heating System Plan

control system. During the heating season (October thru April), finned tube radiators supply heat to the perimeter areas of the building in an amount which increases as the outside air temperature decreases. The hot water heating system circulator pump is started whenever the outdoor temperature falls below 63°F. After the pump is operating, the outdoor thermostat gradually resets the supply water temperature according to a predetermined reset schedule.

Ventilation and Exhaust Systems

A 1600 CFM vehicle exhaust system was designed for the apparatus bay area. The air ducts will be vitrified clay installed under the floor slab. There will be seven single exhaust inlets and two double exhaust inlets recessed in the floor. The estimated cost of the vehicle exhaust system is $2,882.

Separate exhaust/ventilation systems were designed for the latrines, locker rooms, kitchen, apparatus bay, shops, and mechanical room. The ventilation systems will cost approximately $4,520.

Plumbing System

The plumbing system is comprised of several subsystems, each of which is briefly discussed in the following paragraphs. AFM 88-8, Chapter 4, specifies the type and number of plumbing fixtures necessary in a building based on the number of personnel assigned. These specifications were met or exceeded in the design.

Hot and Cold Water Supply. Copper tubing is used for the hot and cold water system. The sizing of water pipes was done in accordance with AFM 85-20 and was based on the pressure available and the quantity of water required. From applicable tables and graphs, the exact size of each pipe was determined. The cold water supply system includes an

overhead truck refill system in the apparatus bay.

The sizing of a water heater for the building was also done in accordance with AFM 85-20. The water heater chosen was a 120 gallon unit with a 98 gallon per hour 100 degree rise recovery rate. A 12 gallon booster water heater was placed in the kitchen for dishwashing purposes.

Waste Piping. The sizing of sanitary waste piping was done to provide the minimum size waste pipes specified in AFM 85-20.

The vent pipes, cleanouts and a grease interceptor were designed in accordance with Air Force Manuals 85-20 and 88-8, Chapter 4.

The design of the storm drainage system was a function of the maximum projected roof area and the intensity of rainfall. Individual drains, gutters and leaders were designed to provide drainage for the maximum intensity rainfall recorded for Dayton. The estimated cost of the entire plumbing system is $41,819.

Kitchen Design

A detailed layout of the kitchen equipment was accomplished in order to determine the maximum demands the kitchen would place upon the electrical and plumbing systems. The kitchen was assumed to be fully equipped and set up to prepare regular meals for 25 persons. The cost of the kitchen equipment and installation was estimated at $12,300.

Mechanical System Costs

The total cost of the mechanical systems in the fire station, less the general contractor's overhead and profit, is estimated to be $100,262.

V. Cost Summary and Recommendations

Cost Summary

The total cost of the fire station, as designed, is $462,647, excluding the general contractor's overhead and profit. This figure is the sum of the separate costs for the building shell ($268,670), the complete electrical and communications systems ($93,715), and the mechanical systems ($100,262). The standard percentage mark-up for a general contractor's margin is normally between 18 and 20 percent of the total project cost including the subcontractor's overhead and profit. As this project would be a government contract, the additional administrative requirements would tend towards the higher value. Therefore, for cost estimating purposes, the 20 percent factor will be used. Adding in the general contractor's overhead and profit increases the overall cost estimate to $555,200 or $34.43 per square foot. Mean's Building Construction Cost Data 1975 estimates the cost of a fire station to be $34.20 per square foot. It should be noted that the cost estimates have been adjusted to the May 1976 time frame as much as possible.

Recommendations

1. The authors recommend that this design be used as the basis for the preparation of contract drawings and specifications for the Consolidated Fire Station Project.

2. The authors further recommend that the Air Force definitive drawings for fire stations be amended to include a provision for a

"drive through" capability option. It was noted during the research for this design that the present Air Force definitive drawings have no such option.

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Variable Volume Air Conditioning System

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An engineering design study was conducted on a proposed consolidated fire station for Wright-Patterson Air Force Base. The goal of the study was to design a specific facility after examining alternate methods of construction and different building materials. Six functional floor plans were considered in the design. The floor plan selected was analyzed using six different structural schemes. A single story design with a drive through capability was selected using a combined steel frame with load-bearing and non load-

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